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GUIDING PASSENGERS IN RAILWAY STATIONS BY UBIQUITOUS COMPUTING TECHNOLOGIES

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ABSTRACT
This paper describes the application of ubiquitous / pervasive computing technologies for the realization of various passenger support systems for use by people including visually-impaired and wheelchair users. We have achieved this goal by building what we call "common information infrastructure" on which you can build various guidance systems in a more cost-effective way. Common information infrastructure consists of a common access interface to user position data based on radio frequency identification (RFID) technologies and a standardized method to describe GIS and guidance data which can be used for a variety of guidance systems. We have also developed prototype guidance systems based on this common information infrastructure.

KEY WORDS
passenger services, barrier-free, universal design, and RFID

1. Introduction

In order to realize user-friendly stations, the creation of a barrier-free physical environment, typified by the installation of escalators and elevators, is very important. In recent years, however, it has become more and more important to remove or decrease information barriers which refers to all the difficulties people, particularly with one or more physical disabilities, experience when they use railways. Based on these considerations, we have carried out research and development into an information provision system that suits the characteristics and situations of the individual users. We have already developed a guidance system for the visually impaired, who are the most disadvantaged in terms of accessibility to information. However, from the viewpoint of those who build the infrastructure of railways, (i.e. railway operators), it is desirable that the information infrastructure for guidance systems for the visually impaired should also form the basis of a guidance systems for other users. Similarly, it is also desirable for the guidance data to be sharable. This paper describes the design and implementation of the common information infrastructure that we propose as an underlying system for several guidance systems for a variety of passengers.

2. Common information infrastructure for personalized passenger support systems

2.1 Needs for personalized guidance

Until now, all railway information has either been in the form of announcements or displayed on screens; passengers have to listen to or view all this information and select what is relevant to them. This type of system makes it nearly impossible to provide the kind of attentive service that would enhance passenger satisfaction. The best choice would probably be to give everyone individualized guidance, but it is not possible for station employees to attend to every passenger individually. Therefore, it is necessary to develop devices and computer software that will give personalized guidance with a conversational interface, even though they may not function as well as a person. We have carried out questionnaire surveys for clarifying the requirements for guidance systems to be used in railway stations. According to the surveys, it became clear that visually-impaired passengers strongly want to obtain personalized guidance provided in a timely manner and that they also want to receive information for avoiding obstacles or potentially hazardous locations. It should also be pointed out that most of them prefer navigation by small, portable type of guidance equipment to robot-assisted navigation. Based on this observation, we have developed a guidance system for visually impaired passengers. Since it is often presented visually, people with impaired vision often have a difficult time obtaining necessary information. RFID tags programmed with location information are installed under the Braille blocks used to mark paths for visually impaired people. An antenna installed in a white cane reads this information, and guidance information is given by a portable user terminal. Of course, the system can be used to inform the users of their present location. Although we have studied several alternative technologies for locating visually-impaired passengers including Bluetooth transmitters, none of them except RFID tags could achieve sufficient level of positioning accuracy to allow them move freely and safely in railway stations where they have to avoid potentially dangerous situations. It is desirable to extend this kind of service to provide personalized information to people with other disabilities and those with no disabilities as well. Unfortunately, however, realizing a fully customized and personalized guidance system for each passenger would be very costly and virtually impossible to deploy in an operational environment. A solution to the barrier-free environment with personalized guidance for every passenger could be universal design. In this concept, "barrier-free" does not mean providing facilities and/or information infrastructures for specific groups of people but instead aims at designing hardware and/or software that are convenient for all users. We aim at realizing an integrated environment in which an optimized solution can be provided for each type of user based on the underlying common information infrastructure. In the following sections, we describe the common information infrastructure that consists of (1) a common location platform, (2) a common geographical information system (GIS) data, and (3) common guidance data.

2.2 Common location platform

We have developed a common location platform based on an RFID tag interface, by which every passenger including visually disabled can obtain information about their current locations at any time. It also makes it possible for a variety of information service applications, including navigation services, to be developed on a common application program interface (API), which will lead to cost-effective system implementation and universal design of user terminals. Here, by the word "universal design of user terminals" we mean that the different users can access the required information by means of the same type of hardware. The basic mechanism of the common location platform we have developed is as follows:

(1) An antenna installed in the top of a white cane transmits a polling signal to an RFID tag embedded under the Braille blocks.

(2) The signal activates the RFID tag, which sends a signal containing location data back to the cane.

(3) Upon receiving the signal, the cane transmits a polling signal which is frequency-modulated based on the latest location data received from the RFID tag.

(4) The polling signal activates an RFID tag, which repeats the process described in (2), whereas the user terminal receives the polling signal and extracts from it the location information that has been obtained through the previous cane-tag interaction.

This mechanism, illustrated in Fig. 1, enables the realization of a common wireless interface for use in both cane-to-tag and cane-to-terminal data transfer as well as the realization of simplified circuits for transmitters and receivers in the cane. We have also developed a device called a "location data transmitter" based on the common

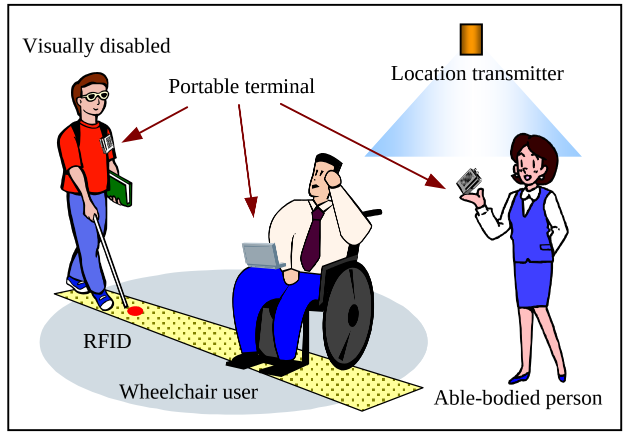

Fig 1: Basic mechanism of common logic platform

wireless interface described above. This device can be installed on a ceiling or on a wall where it is used to transmit location data to user terminals in the immediate vicinity. Since the interface between the terminal and the location data transmitter is identical to that between the terminal and the cane, it is possible for both visually impaired and sighted people to use the same hardware as their portable terminals.

Figure 2 depicts the deployment of the common location platform.

2.3 Common GIS data

Passenger guidance systems require that geographical data be available for the identification of current locations and the calculation of optimal routes to destinations. Although application-specific GIS have been developed in several application domains, for example in car navigation systems, none of them can be used for navigation by pedestrians or passengers. Moreover, GIS data must cover not only stations but also the road environment including streets, shopping centers, city halls and so on, which can be a potential source of or destination for passengers. Considering that seamless information provision covering both railway and road environments is essential for the realization of convenient

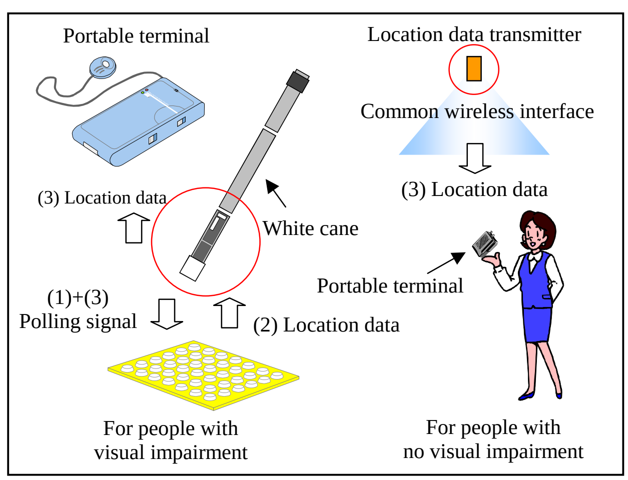

Fig 2: Deployment of common location platform

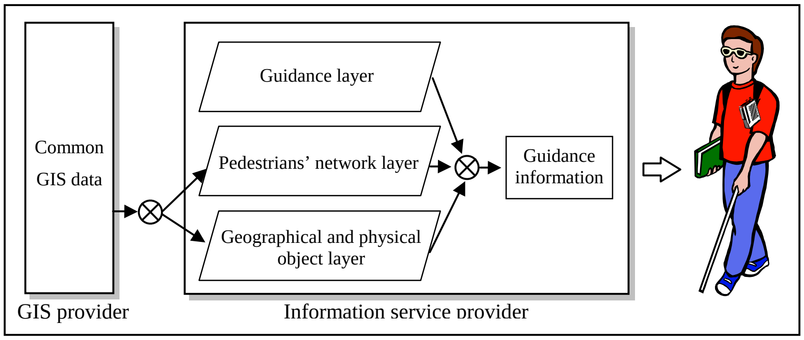

Fig. 3: Common GIS data

intermodal guidance, we have carried out collaborative research into GIS with the National Institute for Land and Infrastructure Management which is mainly engaged in road transport R&D. The goal of this research is to build a common GIS specification applicable to both railway and road environments. Guidance information, which is usually provided to users by information service providers, forms a three-layer structure, as depicted in Fig. 3. The pedestrians' network layer and the geographical and physical object layers contain data that are described using the common GIS specification mentioned above. By separating the guidance layer from the other two layers, it became possible for railway guidance systems to provide railway-specific information while sharing the underlying two layers (i.e. GIS data) with road-oriented pedestrian navigation systems.

2.4 Common guidance data

The main goal of our research is to build a general framework for providing personalized guidance to a variety of users, including people with physical disabilities. Although the need for personalization or individualization is very high, it should also be pointed out that the basic data needed for the guidance of passengers are semantically similar no matter what impairments or disabilities they have. For example, when you are going to get on a train, you may want to know the departure time of your train or the number of the platform from which it is leaving, etc. The basic idea behind our guidance system platform is to establish common guidance data sharable by a variety of users and customize them to meet the demands of each passenger when the data are provided to users. For example, you can customize the method of access to information (i.e. visual, audio, vibration, etc.) or add some supplementary information based on the user in order to minimize physical barriers (e.g., informing wheelchair users of a moving paths where elevators can be used).
Additional consideration must be given to the moving paths of users. Although there are clearly identified moving paths for visually impaired persons (i.e. the network of Braille blocks), this does not apply to other users who can enjoy the complete freedom of two-dimensional movement. When the context of railway passengers is considered, however, it may be reasonable for us to restrict their moving paths where the guidance system can be used to Braille block networks and some additional paths that are frequently used by passengers in general. The guidance data constructed in the way described in this section were provided by an XML(eXtensible Markup Language) format for a variety of users.

3. Prototype system using common information infrastructure

3.1 Basic specification

In order to evaluate the effectiveness of our common information infrastructure, we have developed several prototype guidance systems that share the basic requirement specifications indicated below.
The system must:
(1) Provide features to enable user-friendly voice-based human-computer interaction.
(2) Identify user locations based on the common location platform
(3) Calculate optimal route taking into consideration specific user requirements.
(4) Be built on the same guidance data described in XML.
Figure 4 depicts the general structure of our prototype guidance system. The system consists of two basic components, i.e., a portable terminal and a location identifier. The latter, exemplified by the cane for visually impaired users or a location data transmitter installed in the environment, is a device constantly transmits location data for use by portable terminals. Each portable terminal uses this location data to provide such features as current location guidance, optimal paths calculation, etc., based on the GIS data and specific user requirements stored in the terminal. The voice recognition/synthesis unit in the terminal enables user-friendly human-computer interaction. The main features of the prototype system are depicted in Table 1.
One of the advantages of our system implementation is its stand-alone nature, which means that the systems do not rely on outside communication networks to carry out most of their basic functions. This design decision is based on the requirement that the basic functions of the system, which include voice recognition/synthesis, GIS, guidance database and a route calculation engine, must be provided to users even in the case of communication network

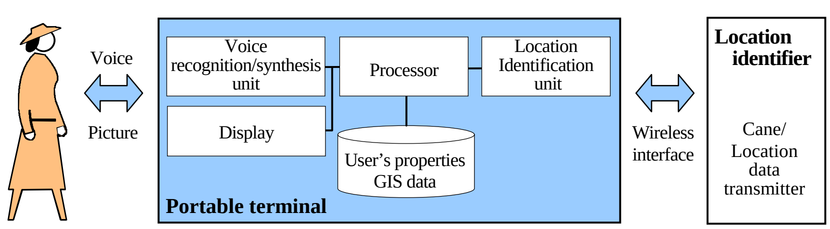

Fig. 4: General Structure of our prototype guidance systems

Table 1: Main features of the prototype systems

modes	features	explanation
Guidance mode	Simple guidance	Inform users of current location
	Navigation	Offer optimal route to the destination
	Station-to-station guidance	Offer guidance on how to get from current station to the destination station
	Date reference	Inform users of current date
	Residual batteries reference	Inform users of residual batteries
	Setting of guidance level	Set guidance level to either simple or detailed mode
Setting mode	Setting of personal data	Set personal data of users including their physical disabilities
	Adaptation to speaker	Adapt the system to a particular speaker in order to improve the accuracy of voice recognition

overload. Building a ubiquitous computing environment does not necessarily mean building a ubiquitous communication network. We have to optimize the distribution of functions over computational resources that are connected by communication networks with limited availability.

3.2 Guidance systems for people with and without visual impairments

Figure 5 depicts the white cane to guide visually impaired people and a location data transmitter for people for people in general. You have only to install our system unit in the top of an ordinary cane will enable it to be used as a location identifier. The unit on the top of the cane consists of a radio antenna, radio frequency (RF) controller and batteries, as is depicted in Fig. 6. The antenna is used to read the location data sent by RFID tags by transmitting polling signals to them. The RF controller is used to receive data from RFID tags and to transmit polling signals that are frequency modulated based on the latest location data received from an RFID tag.
The location data transmitter for people with no physical disabilities transmits the same radio wave as that transmitted by the white cane for the visually impaired people. By installing it on a ceiling or wall it can be used as a location identifier for those in the immediate vicinity.
Figure 7 shows our portable terminal, which resembles a commercially available cellular phone. Of course, its hardware has been completely replaced with that of our system. It weights about the same as an ordinary cellular phone and people can use it without feeling incongruous. This terminal can be used by both visually impaired people and those with no physical disabilities. Modes can be switched at the press of a button.

Fig. 5: White cane for people with visual disability and location data transmitter

3.3 Guidance system for wheelchair users

Although wheelchair users can use the portable terminal mentioned in the previous section, we have also developed a dedicated system for them, as depicted in Fig. 8. The system contains an optical location sensor, which is installed under the chair and makes it possible for users to determine their current location and the direction in which they are heading. It is also equipped with an RFID tag reader, which reads the location data embedded in the RFID tag in the same way as that installed in the cane. Therefore, when a wheelchair user is following the Braille blocks, the system can update the exact current location. The system provides visual as well as voice interfaces, as described in the previous sections.
For the guidance system for wheelchair users, some of the advanced passenger navigation

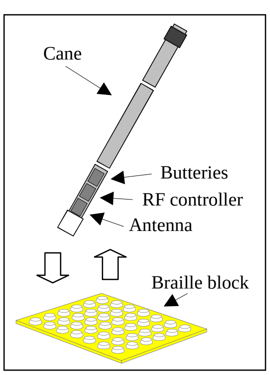

Fig. 6: Structure of white cane for people with visual disabilities

Fig. 7: Portable terminal for people with and without visual

Fig. 8: Dedicated system for wheelchair users

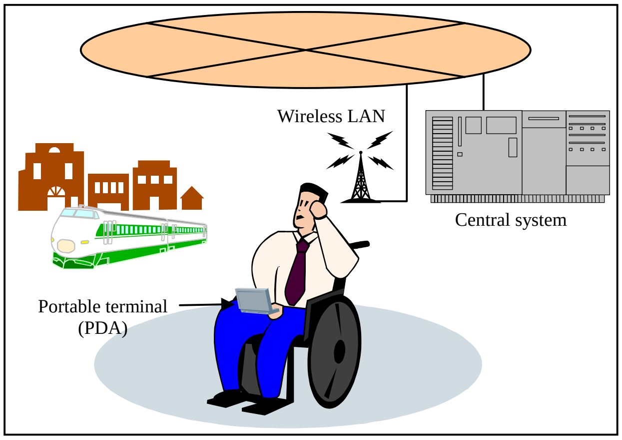

Fig 9: Provision of dynamic information

features were incorporated, including the use of wireless networks to provide dynamic information, as depicted in Fig.9. Examples of dynamic information are as follows:
(1) Information on the train service on which the user will travel
(2) Information on the platform from which the train will depart
(3) Information on places under construction or station facilities whose availability is limited to a certain period of time
(4) Information on alternative transport services (i.e. buses, taxis, trams, etc.)
(5) Up-to-date station map data
Obtaining up-to-date station maps is particularly important from the viewpoint of system operation. Installing maps of all stations in advance is very difficult due to the resource restriction of portable terminals and the map data is subject to change. Therefore, the dynamic loading of map data is mandatory for the system to be fully functional. With this dynamic updating feature embedded in the system, users can always use the latest map data which are downloaded when they arrive at or near a station. It is often required that dynamic information be provided to a huge number of people in a very short period of time, as is the case when train operations are disrupted (e.g., due to an accident, equipment failure, etc.). This requirement would impose a very high performance penalty on the system if one-to-one, connection-oriented communication were to be used between a client (i.e. terminal) and the information server. We therefore implemented the service by using data broadcast technology based on a connectionless communication protocol, avoiding connection-oriented service overload. Portable terminals, which receive broadcast data, automatically filter out unnecessary or unwanted information, as depicted in Fig. 10.

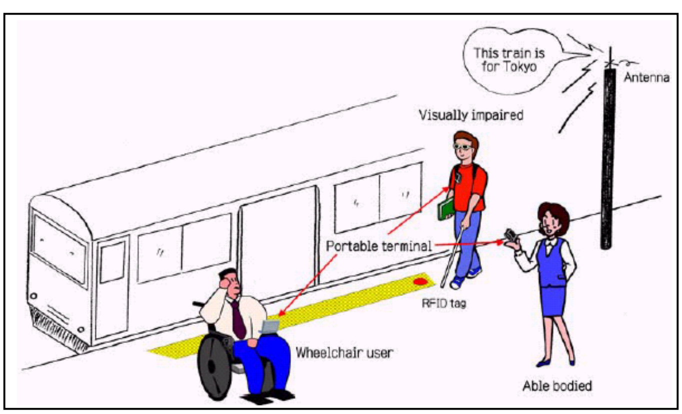

Fig 10: Use of data broadcast technology

Provision of dynamic information is not a specific feature for wheelchair users only, as it will also be provided to other users by implementing appropriate network interfaces to the cellular phone-type portable terminal described in the previous section.

4. Conclusion

We propose a common information infrastructure by which you can build various guidance systems in a more cost-effective way. We have developed a common location platform based on RFID technologies, common GIS data which can be used both in the railway and road environments, and common guidance data which satisfy the requirements of various users. We are currently developing several guidance systems based on this common architecture. Some of the guidance systems are currently under evaluation test in some fields of railways.

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